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Smartphones, Stress, and the Reduction of Cognitive Resources

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SMARTPHONES, STRESS, AND THE REDUCTION OF COGNITIVE RESOURCES

by

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(Under the Direction of Daniel Webster)

ABSTRACT

Smartphones are a ubiquitous part of daily life for most Americans. They offer an abundance of information, connectivity, and entertainment. Previous research suggests that smartphones are also responsible for cognitive costs in educational, public, private and professional settings when in use or audibly creating stimuli in the environment. Smartphones are also linked to an automatic attenuation of cognitive resources even when not in use and merely salient (Ward, Duke, Gneezy and Bos; *Journal of the Association for Consumer Research*; 2, 141, 154, 2017). The purpose of the present study was to experimentally test the effect of cell phone salience (present or absent) on cognitive performance and a physiological measure of stress. Participants were randomly assigned to a group that had their phone present (in front of them) or absent (in another room) Participants completed two separate tasks aimed to measure the cognitive resources (working memory capacity and fluid intelligence) while having their heart rate monitored. Results indicated that that cell phone presence inhibited performance and increased heart rate relative to phone absence. Results support interpretations that cell phone salience reduces cognitive performance and increases physiological measures associated with stress.

INDEX WORDS: Smartphone, Stress, Cognitive Resources, Working Memory Capacity, Fluid Intelligence

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CHAPTER 1: INTRODUCTION

Smartphones are a class of mobile devices with multi-purpose capabilities. They afford the user the ability to call, text message, email, check social media, play games, shop, get directions, trade stocks, video-chat with people from across the world- along with many other possibilities. As smartphones are a relatively new development in society, they bring with them unprecedented connectivity and user engagement. Smartphone users interact with their phones an average of 58 to 85 times throughout the day (Andrews, Ellis, Shaw & Piwek, 2015; MacKay, 2019). Users spend an average of three hours and fifteen minutes per day on their phone, with higher percentile users creeping closer toward five hours each day (MacKay, 2019). According to these statistics, the average user would spend over 49 days of the year on their phone. Effects of smartphone usage on how people think, behave and interact with others have been investigated in a variety of fields. Although smartphones were introduced as devices to increase productivity by way of allowing multitasking, instant connectivity and the availability of unlimited resources, they seem to fall short of expectations by creating new problems (e.g. Turkle, 2011). In fact, because of smartphone-related issues, there is an ever-increasing list of policies that restrict the use of smartphones in settings like schools, professional workplaces, and vehicles. These restrictions are in response to the amount of distraction resulting from smartphones. Today around 96% of American's own a cellphone, and 81% own a smartphone. This is a huge leap from the 35% smartphone ownership in 2011 found in a Pew Research Center survey (2019). For those ages 18-49, smartphone ownership is above 92%. Investigating how these devices can impact the vast majority of individuals is of great interest and importance.

Purpose

The primary purpose of the current study aims to investigate the effects smartphones have on human behavior, and to provide potential explanations for why the phenomena occurs. Specifically, this research takes a deeper dive into how smartphones affect users when not directly in use (i.e. simply near a person). There are two main questions I want to answer with this research: (1) Will an increase in smartphone salience have a negative effect on cognitive performance tasks similar to as seen in Ward, Duke, Gneezy and Bos (2017), and (2) will an increase in smartphone salience increase heart rate- a physiological symptom of stress. I hope to expand the current literature by drawing the relationships between smartphones, stress and cognitive resources. Understanding the negative effects smartphones can produce when they are nearby but not in use can increase productivity and overall physical health.

Smartphone Trends

Research investigating smartphones and other technology in an education setting consistently demonstrates negative effects on academic performance. Students texting or instant messaging during an academically focused lesson took longer to read and comprehend the same material than their focused peers (Bowman, Levine, Waite & Gendron, 2010). On average, they were 22-59% slower than the other groups that instant messaged before reading or not at all- even after subtracting the amount of time it took to send the message (Bowman et al., 2010). In another study, students texting during a lecture scored lower tests of comprehension and factual information presented (Waite, Lindberg, Ernst, Bowman & Levine, 2018). The information missed corresponded with material presented at the exact times the students were texting, providing evidence that multitasking is not effective. If the definition of multitasking is to complete two tasks simultaneously, then these studies are evidence that students cannot interact with their smartphones and simultaneously learn in an academic environment. They can do one or the other- switching their attention to one task at a time. Samples of notes taken by texting and non-texting students revealed that the multitaskers had poorer quality notes (Waite et al., 2018). Multitasking is also a sure way to invite symptoms of stress and anxiety (see Woolston, 2015) and over time, can lead to long-term health problems (American Heart Association, 2019).

Using a smartphone in an academic setting reduces comprehension and speed of learning- even if it is a mere notification. A phone that audibly rings during a lecture can impede all of the students, not just the specific smartphone owner. Information presented while a phone rang was not recalled by the majority of students in the room (Shelton, Elliot, Eaves, & Exner, 2009; End, Worthman, Mathews &

Wetterau, 2010). Vibration mode during class may be ineffective at reducing the negative effects as it can still be audible. On average, people attend to a notification on their phone almost immediately regardless of ring or vibrate mode (Kushlev, Proulx & Dunn, 2016). People can even get the sensation that their phone is vibrating when in reality it has not- which can prompt them to check their phone for a notification. This phenomenon is called Phantom Vibration Syndrome (PVS), and 89% of Drouin, Kaiser and Miller's (2012) participants reported experiencing it at one point in their life. Ironically, the majority of the sample did not believe that this phenomenon was disruptive- much like the students who thought they could multitask. People who perceive a symptom of PVS turn their attention to their phone to check if there was a notification. Regardless if there was a notification or not, their attention was directed to their phone and not on what they were previously doing. If this happened during an academic lecture, previous research would suggest they would not learn the material presented at the time they turned their attention toward their smartphone (see Bowman et al., 2010; End et al., 2010; Waite et al., 2018). Researchers interested in how people manage their smartphone notifications found three main reasons people change the notification setting on their smartphones between ring and vibrate. The most common reason cited by users for turning their smartphone to normal ringer mode was because they wanted to notice the notification, and people reported that they chose to turn their smartphone to silent or vibrate mode to avoid interruptions, or disrupting the environment (Chang & Tang, 2015). Even though silent and vibrate were used to avoid interruptions, vibrate mode and ringer mode did not differ significantly for an SMS notification (Chang & Tang, 2015). Only when smartphone users were not aware of a notification did their general attentiveness to their device slow- but still averaged a check within 1-6 minutes (Chang & Tang, 2015).

Smartphones and Stress

Smartphones are a ubiquitous part of modern American's life. They are theorized as being part of an extended self (Clayton, Leshner & Almond, 2015). This theory was first introduced by Belk (1988) to explain how physical objects are seen as part of the self, due to our ability to control and exercise power over them. Smartphones are frequently paired with the self and self-relevant goals. They are used as alarms, maps, research tools, calendars, etc. They are so powerfully self-relevant that our attentional resources are allocated to them the closer they are to us- even when they are powered off (Ward et al., 2017). Regardless if smartphones are part of the extended self or not, people react to them in systematic ways. The heart rate and blood pressure of participants increased when they were separated from and unable to answer their ringing smartphone (Clayton et al., 2015). Participants in this study were performing cognitive tasks and reported feeling unpleasant during the experiment (Clayton et al., 2015).

Completely silencing a smartphone- or disabling notification seems to be the only way to curb usage. When participants did this as part of an experiment, they reported less stress and higher productivity at work as they were not interrupted during work-related tasks (Pielot & Rello, 2015). Individuals in another study who had their phones completely away from them for a designated period of time also performed better on tasks that require attentional and cognitive resources (Ward et al., 2017). In a home environment however, participants with their notifications disabled but their phone nearby and readily available reported fear of missing out on important information or violating social expectations to respond to others in a timely manner (Pielot & Rello, 2015). Instead of waiting for notification, they felt they needed to check their device for anything that might require a response.

The stress and the compulsion to check for a notification parallels several checking behaviors of those with obsessive compulsive disorder. One of the indicators of a compulsive checking behavior is an elevated belief that there is a responsibility to prevent harm to others (Rachman, 2002). Smartphones are the medium to which we communicate with others in established social norms (e.g., Pielot & Rello, 2015). Participants in Tang and Chang's (2015) experiment reported their peers and loved ones had gotten upset with them, or considered it rude when the participant did not respond to their message. The social norm to respond as quickly as possible had been violated. Participants also reported a fear of violating this norm- even if this did not actually occur (Pielot & Rello, 2015). Checking the notification and responding would avoid the person on the other end of the phone experiencing this discomfort. The social component of the smartphone seems to be emphasized in these cases (see Pielot & Rello, 2015; Roberts, Yaya &

Manolis, 2014; Westermann, Möller & Wechsung, 2015). Notifications for anything socially related are valued most by users (Westermann, Möller & Wechsung, 2015). The stress and discomfort to meet social expectations is relieved by checking the phone (Rachman, 2002). The discomfort relieved by checking behaviors can create a self-perpetuating loop of those same behaviors (Rachman, 2002).

Any factor that produces pleasure has the potential to become addictive (Alavi, Ferdosi, Jannatifard, Eslami, Alaghemandan, & Setare, 2012). Smartphone addiction, or the lack of control with regard to smartphone usage regardless of the negative consequences, is considered a behavioral addiction (Roberts et al., 2014). There are a host of negative consequences that correlate with higher smartphone usage including but not limited to anxiety (Cheever, Rosen, Carrier, & Chavez., 2014; Shoukat, 2019), sleep deficit and depression (Shoukat, 2019; White, Buboltz & Igou, 2010). Generally speaking, smartphone users underestimate how many times they check their phone during the day (Andrews et al., 2015). Screen-recording applications estimate 58-85 checks per day and most are under two minutes (Andrews et al., 2015; MacKay, 2019). Of the small checks 55% are in the 15-30 second focus range (Andrews et al., 2015).

These small checks can be building blocks to an out of control behavioral pattern, and can negatively affect the user in several facets of their life. Are behaviors between smartphone users and their devices a compulsion, dependency or an addiction? Regardless of semantics, most smartphone users spend significant amounts of time on their devices and it affects them systematically.

Cognitive Capacity

The environment offers an abundance of stimuli and the human mind has limits to what it can process- often referred to as cognitive capacity. Colin Cherry (1953) offered one of the first theories to address part of this phenomena, calling it the *cocktail party problem*. His experiments involved presenting participants with either the same message into both ears, or different messages into each ear. He found that people selectively filter information, and if each ear is hearing different messages, only one can be attended at a time (Cherry & Taylor, 1954). Triesman (1964) built upon this and David Broadbent’s filter model to theorize that the human mind attenuates filtered information. This can result in some of the attenuated stimuli to enter awareness. Albeit, the mind automatically processes self-relevant information (Moray, 1959), regardless if it is part of the attended or attenuated/filtered information (Bargh, 1982).

Working Memory (WM) (Baddeley & Hitch, 1974) and Fluid Intelligence (Gf) (Cattell, 1963) are the two main theoretical systems associated with limited-capacity cognitive functioning. These two systems share similar brain activation areas, but are distinct constructs (Clark, Lawlor-Savage & Goghari, 2017). The WM and Gf- described above, are domain general. This means that they do not require the acquisition of specific skills like math or reading comprehension to improve performance.

Working memory is theorized as a “work space” that temporarily holds and processes information pertinent to current task(s) and/or goals (Baddeley & Hitch, 1974). It combines central executive attention and temporary memory storage processes, but is different from short-term memory (Baddeley & Hitch, 1974; Engel, 2002; Engle, Tuholski, Laughlin & Conway, 1999). Likewise, measuring working memory capacity (WMC) includes both memory processes traditionally included in measures of STM such as chunking or rehearsal, with the addition of executive attention capabilities such as maintaining attention while blocking interference (Engle, 2002). Fluid intelligence (Gf) also requires selecting and storing information to use in a goal-directed manner. More specifically it is the ability to solve novel problems without using experiential knowledge (Cattell, 1963). Acquired skills such as math or language ability does not affect performance on tasks measuring Gf (Bilker, Hansen, Brensinger, Richard, Gur & Gur, 2012; Cattell, 1963).

The processes of WM and Gf, although separate are highly correlated. In fact, Gf and WM are more correlated than working memory is with short-term memory (Engel et al., 1999). These two processes guide people through their day-to-day activities, but they have capacity limits to what people can hold in their attention. The automatic attention toward self-relevant information (Bargh, 1982) generally helps WM and Gf processes by directing attention toward relevant stimuli (Shiffrin & Schneider, 1977). On the flip side, automatic attention can also undermine performance. The demands of the environment can exceed the ability of the mind to delegate resources to process it. If the environmental stimuli are self-relevant like a smartphone (see Clayton et al., 2015), but not pertinent to the task at hand, attention may be drawn to it. The effortful inhibition of this stimuli in order to stay on task also takes up limited attentional resources (Engel, 2002), and as it was stated earlier by Woolston (2015) multitasking like this can lead to stress.

The attentional control theory posits that anxiety- the product of a stress response- switches attention from goal-directed to stimulus-directed systems; and consequently, impairs performance (Eysenck, Derakshan, Santos & Calvo, 2007; Eysenck & Derakshan, 2011). This means that when stress is felt, a person shifts their attention from a task or goal they are trying to meet toward the stimuli. For example, say a student is trying to finish their homework but their smartphone keeps vibrating. They would feel uncomfortable stimuli and direct their attention toward that rather than their homework. Inhibiting the stress inducing stimuli or shifting attention away from it uses up the already sparse cognitive resources (Eysenck et al., 2007). It should be understood that the nature of the stimuli fighting for attention both need to be cognitively demanding on resources. For example, it is not hard for the average person to walk and chew gum as neither of those tasks are cognitively demanding. However, if a person is trying to listen to someone talk and simultaneously read a text message on their phone, both sources of stimuli are at risk of not being attended (see Bowman et al., 2010; Waite et al., 2018) as both of these tasks draw on our limited cognitive capacity.

Ward and his colleagues (2017) provided the foundation which this study is built upon. They examined the cognitive costs of smartphones in a novel way- when they are present but not utilized by the user. Through a series of experiments, they found a linear trend of increased smartphone salient decreasing cognitive performance on tasks of working memory and fluid intelligence. The tasks used for this experiment were shorter versions of the original Operation Span (Unsworth et al., 2005) and a subset of the Raven's Standard Progressive Matrices (Raven, 1981). The results pointed to a fight for cognitive resources in a limited capacity environment. They also found an effect of smartphone dependency moderating the intensity of this phenomena. This finding supports research that smartphones and their omni-presence are undermining cognitive performance.

Current Study

An analysis of smartphone research reveals an unexplored connection between smartphones, stress and the reduction of cognitive resources observed when individuals have their smartphones salient in the environment, but not in use (see Ward et al., 2017). The literature demonstrates that just the presence of smartphones can automatically allocate resources away from a cognitively demanding task. No study to date, however, has examined why this occurs. There are theories, but not hard empirical evidence. There is a need for research that determines if physiological stress is present when smartphones are merely salient and not in use. Results stemming from an experimental design may provide more clarity on this matter. Long-term exposure to stress is correlated with a host of negative outcomes throughout life. Proving evidence that stress is present and accountable for the decrease in cognitive performance may change how individuals interact with their devices and can help inform public policies and practices in educational and professional workplaces. It could also be useful for practitioners aiming to help clients manage negative symptoms associated with stress.

CHAPTER 2: METHODOLOGY

Participants

A total of 38 students participated in the study. One participant fell below inclusion protocols for the OSPAN task (see below) and was eliminated from all analyses. The remaining 37 participants were included in all analyses. Inclusion criteria were decided beforehand using prevailing guidelines for operation task and reasoning tasks (Unsworth et al, 2005 and Bilker et al, 2012, respectively). Specifically, it is recommended that accuracy of an operations task remain above 85% and that reasoning task performance remain above three standard deviations below the mean.

The average age of included participants was 21.51 years. Twenty-three participants (62.2%) identified as female, and 14 as male (37.8%). Twenty-five participants identified as White/Non-Hispanic (67.6%), ten as African American (27.0%), one as Asian/Pacific Islander (2.7%), and one as Other (2.7%). All participants were vetted before participation to ensure smartphone ownership.

The required sample size to conduct the analyses for this study was calculated using G Power Analyses (Erdfelder, Faul, & Buchner, 1996). A 2x2 mixed factors ANOVA with an alpha of .05, effect size .25, and power of .8 required a minimum of 34 participants which was met. Independent samples *t*-tests with an alpha of .05, effect size of .5, and a power of .8 required a minimum of 51 participants per condition. Predetermined parameters of the data collection time frame did not allow for the sample size requirements for independent samples *t*-tests to be met. Interpretations of the statistics from those tests should be viewed cautiously.

Research Design

The current study employed an experimental mixed-factorial design. All participants were randomly assigned to either *Desk* (N=19) or *Other Room* (N=18) conditions. Participants' baseline heart rates were measured in beats per minute (BPM). Participants then completed a task of working memory called the *Reading Operation Span (OSPAN)* (task flow shown in Appendix 1) and a task of fluid intelligence called the *University of California Matrix Reasoning Task (UCMRT)* (screenshot of task questions in Appendix 2). Task order was randomly selected and balanced between conditions. Between groups comparisons across conditions and within group comparisons were analyzed.

Procedure

Participants registered in SONA or were recruited through flyers (Appendix 3) posted on a central campus bulletin board. Those who signed up were provided the date, time, location, length of participation time required. Upon arrival, participants were given an informed consent that explained possible risks and benefits associated with the study, confidentiality, compensation, resources available, and participation withdrawal guidelines. Participants read over the informed consent documents and indicated their consent to participate by providing their signature. They were given a copy of this form for their records. After giving informed consent, participants were instructed to create a unique identifier to link together their responses on the multiple tasks assigned to them and their heart rate measurements without using any personally identifiable information (Appendix 4). This unique identifier was then used for all testing measurements.

Once those documents were completed, participants' baseline heart rate was taken and recorded. This was done using a NeuLog Sensor clip on each participants' earlobe- completely sanitized between each participant (NeuLog, n.d.). For one minute the sensor recorded ten measurements per second to calculate an average BPM.

Next participants were assigned their experimental condition (*Desk* or *Other Room*) using block randomization. To begin, all participants in each condition were asked to turn off their phones completely so there would be no sound, vibration, or audible notification. The *Desk* condition required participants to place their phone face-down under the right-hand side of the computer screen. The *Other Room* condition required participants to hand their phone to the researcher who placed it in the other room in a secure area. In place of their phone, the participants in the *Other Room* conditions were given a phone-shaped piece of technology to place under the right-hand side of the computer screen. This technology was an out-of-commission computer hard drive meant to serve as a control. This would ensure that both groups of participants had something of similar size underneath the right-hand side of their computer screen.

Participants in both conditions were assigned to their experimental condition. They completed two cognitive tasks in block randomized order. Each task took approximately ten minutes to complete. During each task, the participants' heart rates were recorded. The NeuLog sensor took ten measurements per second, for ten minutes to calculate an average heart rate in BPM during each task. After completing the cognitive tasks, participants were asked to complete a short demographic survey, given back their smartphone (if they were in the *Other Room* condition) and thanked for their participation.

Measures

Working Memory Capacity. Working memory capacity was measured using an operation reading-span task (OSPAN)- repeating a cycle of memory and processing components (see Appendix 1). Specifically, the OSPAN task calculates each participant's overall percentage of recalled items. The operation span is the most commonly used verbal complex span task. This operation span was developed as an open-source framework using Java and is comparable to the Operation Spans developed by Engle labs (Stone & Towse, 2015). The task flow is as follows: Participants were presented with any number between 1 and 99, followed by a sentence to deem as *Makes Sense* or *Nonsense*, and finally asked to recall the number presented at the beginning of the cycle. This was presented to participants in trials. To begin, participants read over automated instructions that explained the flow of the task and how to indicate their answers. It also included an example series of a trail span. During the task, participants were presented with trial spans of 2-6. A two-trail span would look like this: present first number, sentence logic statement, present second number, sentence logic statement, recall the first number, recall the second number. The participants recall the numbers by physically typing the recalled number on the computer keyboard and hitting enter to indicate their answer choice is finalized. To complete the sentence logic, the participants use the right and left arrow keys to indicate if the logic *Makes Sense* or is *Nonsense*. The trials increased ordinally all the way up to six number presentations, six sentence logic statements, six number recalls.

Fluid Intelligence. Fluid intelligence was measured using the University of California Matrix Reasoning Task (UCMRT). The UCMRT is a tablet-friendly measure of abstract problem solving (see

Appendix 2), and is targeted at populations with high-abilities, such as college educated students. It has convergent and external validity with the Raven's Advanced Progressive Matrices- the most common test for fluid intelligence (Bilker, et al., 2012; Cattell, 1963; Pahor, Stavropoulos, Jaeggi & Seitz, 2018). The task instructs participants to indicate what matrix element, out of eight options along the side of the screen, completed a three-by-three pattern. Participants completed an automated practice test prior to attempting to solve 23 individual matrices in an allotted ten-minute testing frame. The practice test included three problems to solve and indicated participants' accuracy. The number of correct items out of the 23 questions was calculated into a percentage score.

Heart rate. Heart rate was measured using a NeuLog Sensor clip on each participants' earlobe- completely sanitized between each participant (NeuLog, n.d.). To record baseline measurements, the participants were instructed to sit with their feet flat on the ground, arms supported by their lap, and back resting on the back of the chair (American Heart Association, 2015). For one minute the sensor recorded ten measurements per second to calculate an average heart rate in beats per minute (BPM). During each task, the NeuLog took ten measurements per second for ten minutes (the duration of each task) to calculate average heart rate during that time frame. Participant heart rate was not recorded during each task's practice test or instructions. Change scores between the baseline and during each the UCMRT and OSPAN were used for analysis. The change score was calculated by taking the difference between the baseline heart rate and the task heart rate. Change score for UCMRT was calculated by subtracting baseline heart rate from the average heart rate during the UCMRT. Change score for the OSPAN was calculated by subtracting baseline heart rate from the average heart rate during the OSPAN.

Planned Analyses

The UCMRT performance scores were analyzed between conditions using an independent samples *t*-test, and the OSPAN performance scores were analyzed between conditions using an independent samples *t*-test. Heart rate was converted to a difference score (task heart rate – baseline heart rate) and analyzed using a 2 Condition (*Desk*; *Other Room*) x 2 Task (*UCMRT*; *OSPAN*) mixed analysis of variance (ANOVA) with condition as the between-subjects factor and task as the within-subjects factor.

CHAPTER 3: RESULTS

Preliminary Analysis

Baseline. Baseline heart rate measurements were compared for the *Desk* and *Other Room* condition using an independent samples *t*-test. Results indicated a significant difference $t(35) = 2.5$. $p = .017$ between the heart rate measurements of two groups such that the participants in the *Other Room* condition had a higher baseline heart rate (M =75.32, SD = 12.03) relative to those in the Desk Condition (M =66.48, SD = 9.42). Given that the physiological measure of stress (heart rate) in the current study is calculated as a difference from baseline, it alleviates concerns about absolute group differences at onset.

Primary Analysis

Working Memory Capacity. In order to investigate group differences on working memory capacity, an independent samples *t-test* was used to compare the OSPAN scores between the *Other Room* and *Desk* conditions. Results indicated that participants in the *Other Room* condition performed significantly better (M =64.24, SD = 6.05) than those in the Desk condition (M =57.80, SD = 7.08), $t(35) = 2.965$, $p = .005$.

Fluid Intelligence. The fluid intelligence group difference was analyzed in a similar manner. An independent samples *t*-test compared scores on the UCMRT between the *Other Room* and *Desk* conditions. Results supported the prediction that those in the *Desk* condition had lower performance scores on the UCMRT (M =63.28, SD = 9.10) than those in the *Other Room* condition (M =51.55, SD = 12.13), $t(35) = 3.312$, $p = .002$.

Heart Rate. To address this research question, a 2 Condition (*Desk*; *Other Room*) x 2 Task (*UCMRT*, *OSPAN*) mixed model ANOVA with condition as the between-subjects factor and task as the within-subjects factor was conducted with heart-rate change (heart rate change from baseline) as the dependent measure. Results revealed a main effect of Condition such that heart rate increased more for those in the *Desk* condition (M = 7.69 BPM, SD = 5.82) compared to participants in the Other Room condition (M = .68 BPM, SD = 2.3), $F(1,35) = 24.40$, $p < .001$, $\eta_p 2 = .41$. There was also a main effect of task such that heart rate increased more under the UCMRT (*M* = 4.71 BPM, *SD* = 5.78) than under the OSPAN (*M* = 3.85 BPM, *SD* = 5.55), F (1,35) = 4.89, p = .034, $\eta_p 2$ = .123. The interaction was not significant, $F(1,35) = 1.122$, $p = .297$, $\eta_p 2$ = .031.

CHAPTER 4: DISCUSSION

Review of Purpose

The current study aimed to investigate the effects smartphones have on human behavior and provide possible explanations to the effects. There were two main questions I wanted to answer when conducting this research: (1) Would an increase in smartphone salience have a negative effect on cognitive performance tasks similar to as seen in Ward et al. (2017), and (2) would an increase in smartphone salience increase heart rate- a physiological symptom of stress. Smartphone salience is ever-increasing in the world today, and can be unknowingly undermining the performance of individuals and causing unnecessary stress (Pew Research Center, 2019; Ward et al., 2017; Westermann, Möller, & Wechsung, 2015).

Effectiveness of the Manipulation

The manipulation in this study was implemented directly after the baseline heart rate measurements were recorded. All participants were asked to place their smartphone in a completely silent mode so that no ringing, vibration or any audible sound could occur during the remainder of the study- most of which had done this already before being asked. Even though the participants' smartphones would not make any noise during the experiment, their mere presence has shown to draw the user’s attention away from other cognitively demanding tasks (Ward et al., 2017). It is commonplace in settings such as this for individuals to be asked to do something with their smartphone (think doctor’s offices, classroom, etc.) so there were no objections from any participants. After this those in the *Desk* experimental group were asked to place their smartphone face-down underneath the right-hand side of the computer screen. Participants in the *Other Room* experimental group had their smartphone placed in the designated area outside the room and handed a phone sized/shaped computer hard drive. They were asked to place this underneath the right-hand side of the computer screen instead. Participants in the *Other Room* experimental group did not stand to move their own smartphone as this would have affected their heart rate. The object handed to those in group *Other Room* served as a control so that both groups had a piece of recent technology underneath their computer screen and in their field of vision. Participants had no connection to this piece of technology like they do their own smartphone (Clayton et al., 2015) so it was predicted that this control would not have an effect on task performance scores or heart rate. Once the manipulation had been completely implemented, participants moved forward in the experiment.

Performance Score Effects

Participants in this study were randomly assigned to either experimental condition (*Desk, Other Room*) in an effort to balance individual differences across groups. Those in the *Desk* condition, who had their smartphone directly in front of them, were hypothesized to demonstrate poorer performance on the tasks. Results fully supported previous literature and the hypothesis that those who had their smartphone in front of them performed significantly worse on the UCMRT and OSPAN than the group with their smartphone in the other room. This shows that the manipulation produced the expected effects. It provides additional support for Ward and colleagues (2017) who discovered this phenomenon. This finding is useful in many aspects. If individuals are finding themselves distracted whilst at work, in school, or driving -all cognitively demanding tasks (Healey & Picard, 2005; National Safety Council, 2012), putting their smartphones away is a viable solution to streamline attentional resources. Additional research could incorporate real-time screen usage reports (an included feature on most newer smartphone models) into the analysis to see if those who spend more time on their smartphones are affected by this phenomenon worse than those who spend less time on them. This is seen in some studies (Cheever et al., 2014; Ward et al., 2017), but was not examined in the present study.

Heart Rate Effects

In addition to the replication of Ward et al. (2017), the current study extends these results by investigating a physiological measure associated with stress (heart rate). While each participant was performing the UCMRT and the OSPAN, their heart rate was measured and then compared to their baseline heart rate. Participants who had their phone on the desk showed a significant increase in heart rate during the two tasks when compared to the participants in the *Other Room* condition. Having their smartphone on the desk raised participants' heart rates over 7 BPM during this experiment. Additionally, the main effect of heart rate change with the UCMRT and OSPAN between both experimental groups suggests that each task's difficulty may independently effect heart rate (albeit small 1 BPM).

Evidence that phone saliency impacts this physiological measure has implications for associated stress. Over time, consistent experiences of an elevated heart rate from momentary stressors can contribute to long-term anxiety and overall heart issues such as hypertension, heart attack, stroke, or heart disease (American Psychological Association, 2019; Matthews, Katholi, McCreath, Whooley, Williams, Zhu, & Markovitz, 2004). In a real-world setting, if people are placing their smartphones on their desk at work or school, or near them while driving, they could be unintentionally increasing their heart rate each day leading to a host of health issues in the future. This research shows that leaving your phone in another room, away from sight and turned off could prevent this daily stressor.

Implications

This research advocates for the *out of sight, out of mind* mantra. In the current study, the manipulation of an individual's smartphone either on their desk while they work, or outside the room while they work showed a significant difference on individual performance on cognitive tasks and heart rate elevation. For maximum productivity in the workplace or educational setting, smartphones should be placed away and, in a setting, where no audible ringing or vibrating can be heard. In consideration of physical and mental health, individuals would benefit from this as well. Long-term exposure to stressors such as smartphone-induced heart rate elevation could have long-term health consequences. Employers and educators could use this as a basis for smartphone usage policies in certain settings. As much of the workforce has transitioned to work-from-home and distance-learning due to the COVID-19 pandemic, this information is useful to help create a productive environment that is free from unnecessary stressors. Additionally, clinicians might offer this to clients expressing difficulty with productivity or stress in cognitively demanding settings. This information could also be useful for the creation of public policy. Although most states in the U.S. have strict laws regarding smartphone use while behind the wheel, this research offers further insight. It shows that a smartphone does not have to be in use for adverse effects to occur, merely salient. Driving is a cognitively demanding task (Healey & Picard, 2005; National Safety

Council, 2012) and a salient smartphone can take away from the resources needed to safely operate a vehicle. Drivers would be safer if they put their phone off and away from sight while behind the wheel.

There are theories that people think of their phone as an extended self (Clayton et al., 2015), are addicted to smartphones (Roberts et al., 2014; Roberts, Pullig, & Manolis, 2015; Shoukat, 2019; Alavi et al., 2012), are bound to their smartphone by social norms that need to be upheld (Pielot & Rello, 2015). Stress lies at the root of all of these theories, which is why the current study investigated what the body is actually doing when individuals are performing cognitively demanding tasks with their smartphones near them. The measured physiological symptom of stress was heart rate, as it is the least intrusive and is highly reactive to momentary stress (American Psychological Association, 2019).

Limitations

The current study included a few limitations worth noting. Including more participants would be ideal for generalizability to the general population. Moreover, the population included is predominantly white, college-aged, college-educated, female participants which contributes further to issues of generalizability. It is important that future studies gather a larger, more diverse sample population including older participants of varying education, and those who identify as ethnic, gender and sexual minorities. Additionally, the sample size did not allow for particularly rigorous statistical analysis. Future replication and extension of this study should require a larger sample size to investigate the effects order may have on participants' heart rate change as the tasks themselves could be having an independent effect on experienced stress.

Overall Conclusions

This study reveals support for previous findings that smartphone salience negatively impacts performance in cognitively demanding tasks and increase a physiological measure of stress (heart rate). When participants were completing tasks that required working memory and fluid intelligence, having their smartphone in their field of vision reduced performance for both tasks and induced an elevated heart rate - a sign of stress. This research provides insights into the smartphone-user relationship that are valuable to a world that is always connected. As technology promises increasing productivity and connectivity, it remains important to explore costs associated with these promises.

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APPENDIX A

OSPAN TASK FLOW

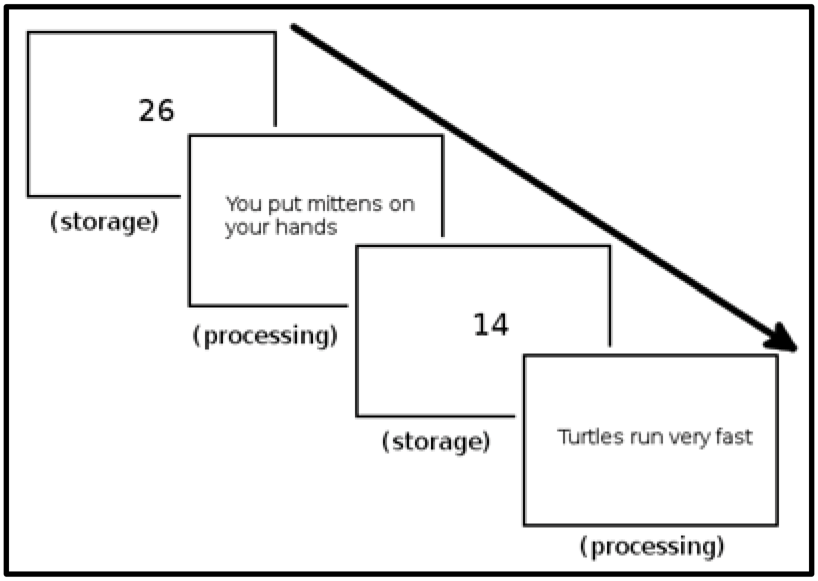
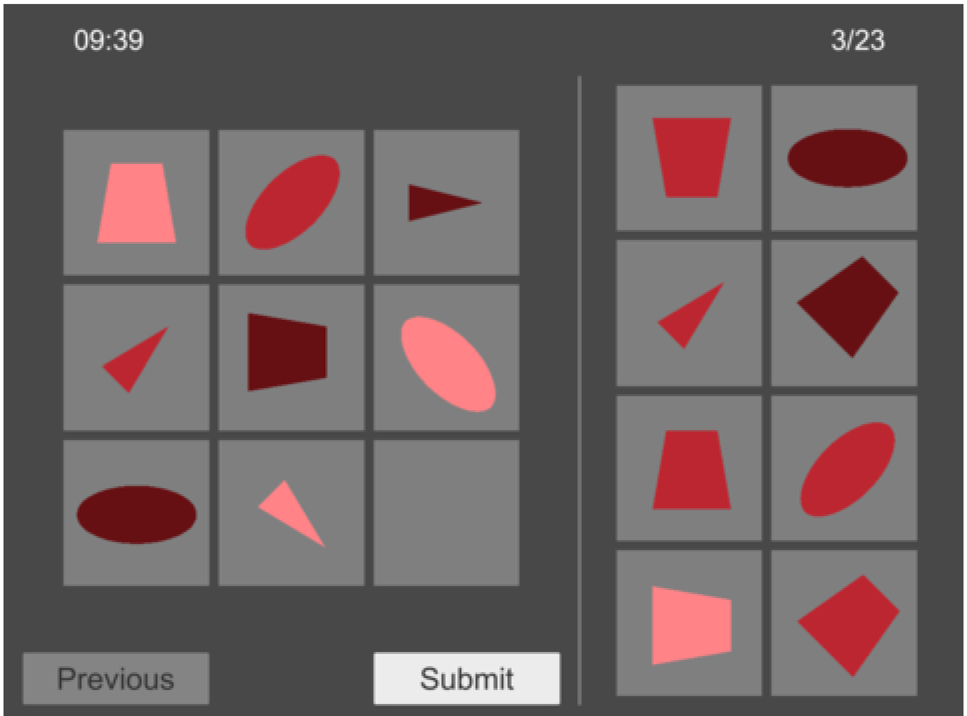


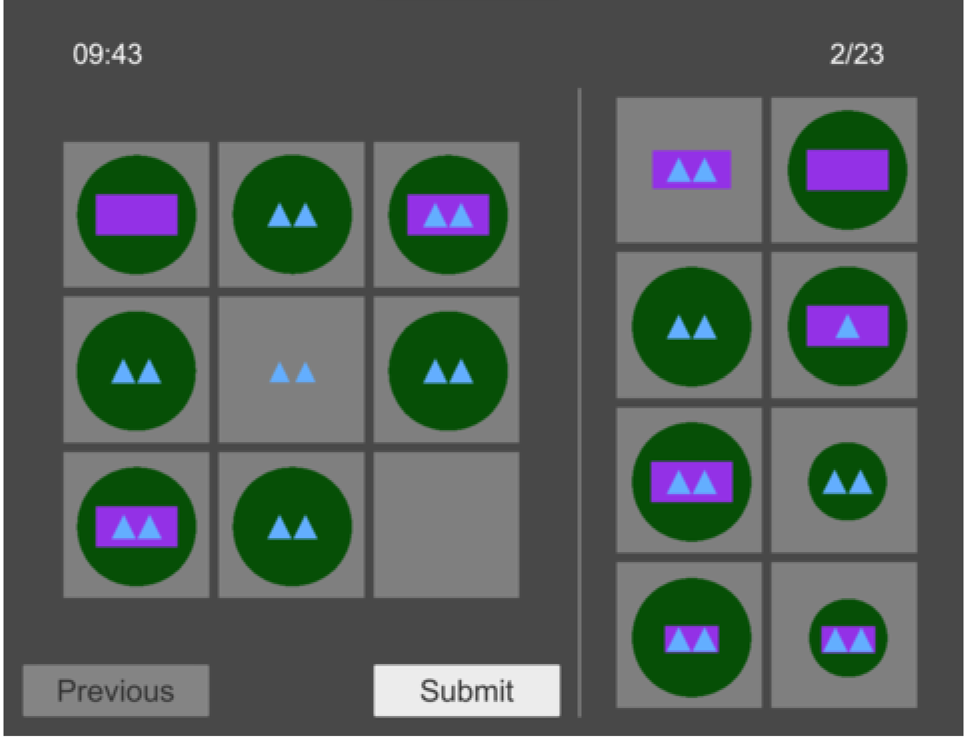
Illustration of OSPAN task. Credit: Stone & Towse, (2015)

APPENDIX B

UCMRT SCREENSHOTS

UCMRT screenshot. Credit: UCR Brain Game Center

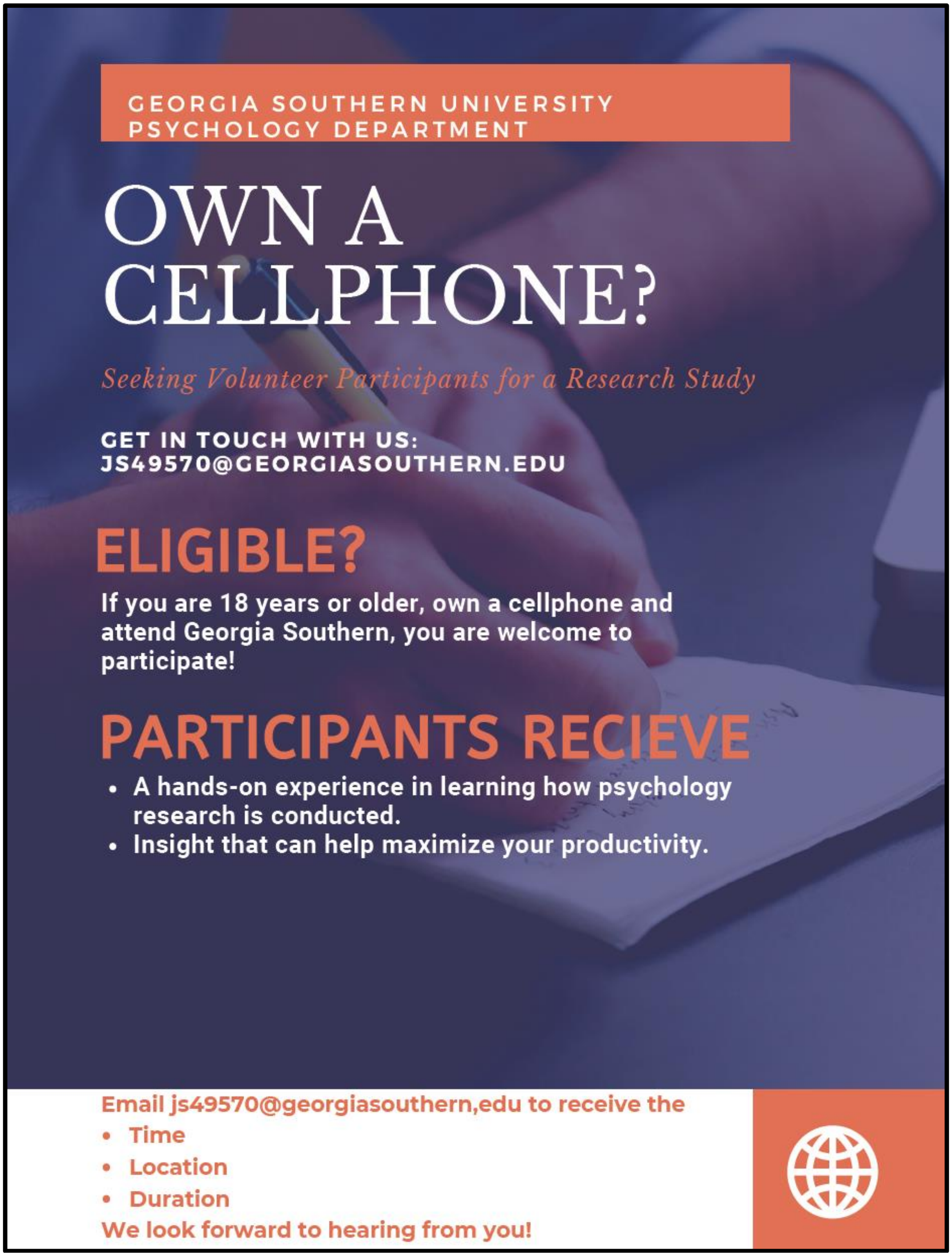




UCMRT screenshot. Credit: UCR Brain Game Center

APPENDIX C

RECRUITMENT FLYER



APPENDIX D

UNIQUE IDENTIFIER

Cognitive Resources

Creating an identifier for this study

You will be asked in this study to complete several different tasks; identifiers are used to help keep your responses together without anyone being able to tell WHO the responses are from. You will not place your name on any of the materials you complete for this study, instead you will use your identifier. While you may use anything, you would like for your identifier you would not want to use something like your Social Security number since it may be possible for someone to identify you through it. A procedure suggested by the Georgia Southern IRB (Institutional Review Board) for creating identifiers follows.

Georgia Southern Institutional Review Board Suggested Procedure for Avoiding Traceable Identifiers (such as Social Security Number-SSN)

The following is a suggested procedure to be utilized by researchers conducting a longitudinal study and therefore needing to be able to link a subject's responses across time, yet still maintain a high degree of confidentiality, or even anonymity. This is accomplished by instructing the subjects/participants to create an identifier which will have two characteristics: 1) it will be known only to them and; 2) it can be recreated at any time with virtually no role to be played by the subject's/participant's memory.

To do this, a four-part identifier will be created which will consist of a letter, followed by two numbers, followed by another letter, as follows:

- The first letter is the first initial of the subject's/participant's mother's first name.
- The two numbers represent the month of the subject's/participant's mother's birthday (i.e., not the year or the specific day).
- The final letter is the first initial of subject's/participant's mother's "maiden" name

For example:

- If the respondent's mother: Harriet Cone, were born on April 14, 1942, the identifier would be: H04C
- If the respondent's mother: Charlotte Bronfman, were born on November 4, 1900, the identifier would be: C11B

Create your identifier ____

Please use this identifier on all of the forms that you complete for this study.